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Urine a source for struvite: nutrient recovery – A review

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Urine is not a waste but can be a raw source for struvite ($MgNH_4PO_4.6H_2O$) which can be used as a substitute of fertilizer, since direct usage of urine have demerits such as it is not easy to store large quantity of urine at a place prior to use, it is also not economic to transport collected urine in large volumes, it will have some soil-nutrient ill effects, urine when not properly disposed it can lead to eutrophication, odor problem, contamination to drinking water bodies and have pathogen risk for humans but with struvite use these issues can be minimized and it is cheap to transport solid struvite. Because of the increasing prices in the market of chemical fertilizers, struvite production is important for the recovery of nutrients. Fertilizer industries also produce Greenhouse gases while struvite, when produced at large scale these emissions from industries, will be minimized because it will reduce the burden of fertilizer industries of producing more quantity of chemical fertilizers. Production of chemical fertilizer required phosphate which is available by extracting phosphate ores resulting in exploitation of this natural resource. The struvite can be produced by chemical or electrochemical processes by using salts of magnesium or by using magnesium plates respectively with urine as a source. This review will help in understanding that why it is essential to produce struvite. The chemistry behind the precipitation of struvite, what essential nutrients it has so that it can be used as an alternative to fertilizers for plant growth, its economic value and with this many environmental problems can be reduced.

Keywords: Urine, precipitation, phosphorus, struvite, fertilizer.

Introduction

Human urine is considered as one of the common wastewater. In various regions of the world where there is human habitat, they are involved for generating the majority of waste and one of them is urine, but this urine can be used as a raw source to generate struvite. After the blood filtration in the kidneys urine is produced and because there is no filtration of proteins, therefore, it has low molecular weight compounds. Urine is rich in N, P, K concentration[1] and these are requisite facet for agricultural productivity[2]. Both phosphorus and nitrogen are very important nutrients for the agriculture and plays a very vital role in the development of global food production[3], therefore the recovery of these nutrients is very essential at the global level.

Because of the ill effects of chemical fertilizers and extinct of organic raw products in the field of agriculture, there is the gain in the popularity of human urine for its application for crops as a substitute of fertilizer in a number of countries for farming[4]. As a slow-release fertilizer struvite can be used[5] and it can also reduce a load of P from the wastewater and minimizes the treatment in downstream by internal recycling[6]. Maurer *et al.*[2] studied different literatures and states that there are different number of technology present and used for the treatment of collected urine which include reverse osmosis, freeze-thawing, struvite formation, ammonia stripping for N recovery and many others but out of these large number of methods very complex to use and not holds good for large scale application. Ammonia stripping can be done to the stored urine as a pre-treatment which will help in reducing the loss of nitrogen during solar evaporation[7]. In polluted water when loads of nutrients are high it can stimulate the growth of algae and this can cause unbalance in the ecosystem structure by forming hypoxia or anoxia zones[8].

Formation of struvite ($MgNH_4PO_4.6H_2O$) which have crystalline structure takes place when the species namely magnesium, ammonium, and phosphorus have a value in the ratio of 1:1:1 molar concentrations under a specific range of pH, temperature, the rate of aeration, etc.[9]. Usage of unnatural chemical fertilizers to a large extent can result in the decline of nutrients in soil[10]. Fertilizers industries also produce carbon footprint by the emission of various greenhouse gases, as a result, the climatic changes are occurring. When recovery of essential nutrients will be done it will reduce the production of chemical fertilizers and will help in the reduction of greenhouse gases making the climatic conditions to be balanced across the globe. Struvite has greater market demand and can be applied straight to agricultural fields for crop growth as slow release fertilizers (Munch *et al*., 2001).

Human urine characterization

The rate of generation of human urine per person per day is 1 to 1.5 liters. The adults release urine per year on an average of 500 liters whereas the children release urine per year nearly 0.5 times of adult value[10]. Fresh undiluted urine has a pH value of about 6 and also contains some important elements that support crop growth. The concentration of these elements are (g per L) nitrogen 7–9, phosphorus 0.20– 0.21, potassium 0.9–1.1,sulphur 0.17–0.22 and it also contains magnesium and calcium (g per L) as 1.5–1.6 and 13–16 respectively. More than 90% N, P, K is available in urine as an inorganic form which are highly important to replace fertilizer for agricultural fields[11]. Nitrogen is excreted nearly about 75 to 90% in the form of urea and the remaining is in ammonium or creatinine form[12]. The heavy metal concentration in human urine is less when compared with farmyard fertilizer and it also has a lower concentration of cadmium than P fertilizers which make urine a clean fertilizer[13]. Urine also have some composition of trace elements such as B, Cu, Mo, Zn, Fe, Mn and Co[14]. The composition of human urine changes from one individual to another and the cause of this variation is age, health, diet, region and many other factors related to everyday life.

Storage of urine

Fresh urine has a pH of about 6 but when urine is stored around 90 days it will have a pH value of about 8.9[11]. In urine, nitrogen is found in the form of urea. On storage, hydrolysis of urea occurs resulting in the formation of ammonia and bicarbonate as shown in eq. (1) giving alkalinity and causing pH to rise (Udert *et al*., 2003).

$$NH_2(CO)NH_2 + 2H_2ONH_3 + \rightarrow NH_4^+ + HCO_3^- \quad (1)$$

Human urine should be stored for 180 days or more at 20°C which is safe to use when harmful viruses and pathogens have to be inactivated (Vinneras et al., 2008).

Struvite precipitation chemistry

In human urine, the chief ingredients are urea and nitrogen which are primarily present in organic form and largely as urea (Beler *et al*., 2011). Compared in human feces and urine as a whole, most of the nitrogen (90%), phosphorus (65%) and potassium (80%) are found in urine (Van wijksijbesma 2005).

Struvite has orthorhombic structure and it precipitates as magnesium ammonium phosphate hexa hydrate or MAP. The color of struvite can be white, brownish white or yellowish white. The principal elements for the struvite (MAP) to be precipitated are magnesium, ammonium and phosphate[15]. Struvite precipitation is favored if Mg, NH_4^+ and PO_4^- are present in molar concentration of 1:1:1 (Doyle *et al*., 2001), as indicated in eq. (2).

$$Mg_2^+ + NH_4^+ + PO_4^{3-} + 6H_2O \rightarrow MgNH_4PO_4.6H_2O \downarrow \quad (2)$$

Ammonia in adequate quantity is present in urine but urine has a deficiency in magnesium[4], hence magnesium is added externally for the MAP formation as shown in Fig. 1.

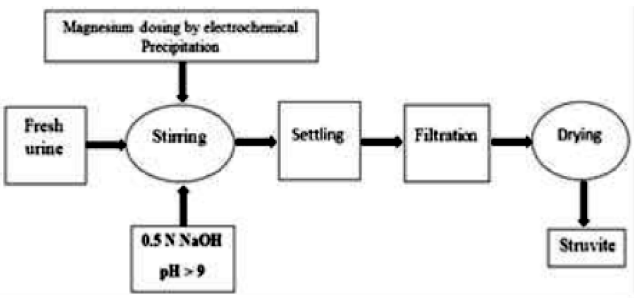

Fig. 1. Flow diagram showing the struvite formation process.

The formation of crystals of struvite is pH dependent[16] whereas it also depends upon other factors like molar ratio, temperature, aeration rate etc.

Effect of molar ratio

Different types of magnesium salts were used to input the dosage of magnesium for the precipitation of struvite because urine has a deficiency in magnesium so it is added externally. $MgCl_2$ is used by many researchers for struvite precipitation as a source of magnesium but other salts of magnesium such as $MgSO_4$, MgO and $Mg(OH)_2$ were used by very few of them[17] studied and observe not much of differences for the removal of NH_4-N, COD, and color by using magnesium in the form of $MgCl_2$ and $MgSO_4$. However, when MgO is used there is much lesser removal of color, NH_4-N, and COD[18] stated that in most of the cases for the formation of struvite the effective ratio is either 1:1 or 1:1.2.

Zhang *et al.*[19] observe that for the removal of ammonium and concentration of PO_4^{3-} the most suitable ratio of Mg^{2+}:NH_4^+-N:PO_4^{3-} must be 1.15:1:1. Kozik *et al.*[20] observe that when the PO_4:Mg molar ratio was 1 and pH of the solution is 9 the average size of the struvite crystal was 42 μm but when within 30 min. the ratio was changed to 1:1.2 the crystal size increases to 58 μm. Under the same condition when the reaction time was increased to one hour and the molar ratio of PO_4:Mg was 1 and 1:1.2 the size further increases to 67 and 80 μm for both the ratio respectively.

Effect of pH

pH also plays a vital role in the precipitation of struvite. Hao *et al.*[21] observe that MAP precipitation can occur under a wide pH range of 7 to 11.5, but the suitable range for MAP precipitation is 7.5 to 9.The rate at which there is a decrease in pH of the solution it will show the speed of growth rate of struvite crystal and the quality of struvite so precipitated is also dependent on the pH, therefore pH can be used for the indication of nucleation for struvite[21].

At pH of 8.5 MAP was formed recovering nitrogen and phosphorus from stale human urine (Zhigang *et al.*, 2007). Buchanan *et al.* (1994) studied and observed that minimum solubility of struvite occurred at pH about 9.0 also (Matynia *et al.*, 2006) observed that by increasing the pH value from 8 to 11 the mean size of struvite crystal decreased by five times. Adnan *et al.*[15] studied that when the operating pH is up to 8.3 the P removal will be more than 90%.

Effect of temperature

Ali *et al.*[23] stated that when struvite was boiled at temperature less than 100°C for 24 h it will partially be converted in to bobierrite a shows gradual decrease in ammonia and when struvite is boiled in excess of water it will show that the 5 water molecules are lost from struvite and will be converted into monohydrated dittmarite.

Hao *et al.*[21] studied the crystals of struvite and states that when pH of the solution was kept between 7 to 7.5 for 90 days under 25 to 30°C temperature 99.7% of crystals of struvite was formed. With the increase of temperature, the purity of struvite also increases this statement holds true as the solubility product of struvite decreases when the temperature rises. Its solubility is lower when temprtaure is between 15°C and 30°C but rises when the temperature is more than 30°C[24].

Comparison for production of conventional chemical fertilizer with struvite

Chemical fertilizer:

Chemical fertilizer is a substance produced from the naturally occurring minerals which when applied to the soil or to the agricultural land will provide essential nutrients to the crop for their growth and development. Fertilizers are primarily used in ancient time by farmers at that time and from that time till now it is used with modern technology for their production. The production of fertilizers required natural minerals and these are limited like that of coal and petroleum. Nitrogen, phosphate, and potassium with some secondary nutrients are the major ingredients of the fertilizers that are used by farmers of the modern era. These chemical fertilizers, therefore, required phosphate which is available in the phosphate rock form and it is natural rock that is disintegrating with the production of fertilizers and it has been predicted that by 2033 the global production of phosphate rock is at its peak and as a result of which the demand will exceed the supply for the phosphate fertilizers[3], therefore a long term use of chemical fertilizers is the concern for the environmental engineers.

The NPK written on fertilizers bag which shows the amount of available plant nutrient with a guarantee in that bag and is expressed in terms of percentage by weight in a fertilizer such as 12-32-16 is a type of NPK grade fertilizers representing 12% nitrogen, 32% phosphorous and 16% potash. The fertilizers can be classified as straight fertilizers and complex fertilizers. Fertilizers having N, P or K as major nutrient are straight fertilizers while fertilizers having at least two major nutrients out of three are complex fertilizers [FAO][25].

Raw materials for fertilizers:

The materials that are indicated here are those of complex fertilizers which are made up of primary fertilizers and secondary nutrients. These raw materials can be supplied to fertilizers production industries in bulk quantities like thousands of tons in the drum or in bag containers in solid form.

Primary fertilizers are consist of substances which are derived from nitrogen, phosphorus, and potassium.

For nitrogen source ammonia is used and which is produced with the use of air and natural gas, for phosphorus source coal, sulfur, and the natural rock of phosphate are used and potassium chloride which is the primary component of potash is used as potassium source. To make the fertilizers more effective secondary nutrients are added into fertilizers. Limestone is used to extract the calcium which is in the form of calcium carbonate, calcium sulfate, and calcium magnesium carbonate. Dolomite is used for extracting magnesium. Sulfur is also added and some other materials such as iron are extracted from ferrous sulfate and molybdenum oxide and are used to extract copper, and molybdenum is also used in the production of fertilizers.

Manufacturing process of fertilizers:

To produce the complex or compound fertilizers industries are designed in an integrated way so that they produced the required fertilizers, the process for manufacturing fertilizers differ from one manufacturer to other depending upon the required end product.

Nitrogen component for fertilizer:

The atmosphere of earth is composed of a large portion of nitrogen which when processed through proper processes can be the cheap raw source for production of nitrogen. Haber process is used for the production of ammonia from the nitrogen and hydrogen. This process consists of pumping the natural gas with steam into a large vessel, after this in this system air is also pumped and by burning of steam and natural gas the oxygen is removed. This will give hydrogen, nitrogen and carbon dioxide. Then in the system an electric current is introduced and with the use of this electric current carbon dioxide is removed and ammonia is produced to improve the synthesis of ammonia catalyst like magnetite can be used, this ammonia after removing impurities is stored in a tank before its further use.

Sometimes ammonia itself is used as fertilizer and sometimes for ease of handling of ammonia it is converted into some other product. By mixing air with ammonia nitric acid is produced in a tank. Ammonia is converted into nitric oxide with the help of a catalyst, then with the reaction of water with nitric oxide will produce nitric acid. Then to make ammonium nitrate this nitric acid is used. As it has a high nitrogen concentration is very good fertilizer component in a tank, two materials are mixed and neutralization reaction happens to produce ammonium nitrate, then this material is stored till it is ready for granulation and blended with other components of fertilizers.

Phosphorous component for fertilizer:

The main ingredient of phosphate is the phosphate rock which is a natural resource. To extract phosphorus phosphate rock is used and for this phosphate rock has to be treated with sulfuric acid to produce phosphoric acid and further some of this material is reacted with nitric acid and sulfuric acid for producing triple superphosphate, this triple superphosphate is in solid form and it is an excellent source of phosphorus. Then in another separate tank, some phosphoric acid is reacted with ammonia to produce ammonium phosphate another excellent primary fertilizer.

Potassium component for fertilizer:

The main source for this component of fertilizer is the potassium chloride which is supplied to the manufacturers in large quantities. Potassium chloride by granulation is converted into a usable form which will make it easier to mix with other components of fertilizers.

Granulating and blending:

The different compounds that are produced before such as ammonium nitrate, potassium chloride, ammonium phosphate, and triple superphosphate in solid form are now granulated and blended in order to produce the most usable form of fertilizer. A rotating drum with an inclined axis is used for the granulation process in which solid form of different components are put together and it will rotate and solid is converted into small spherical shapes by rotating. After which their screening is done which will separate adequate particles, then to make each particle discrete and moisture retainable their coating is done with inert dust and at the end of the process, these particles are dried.

For the production of composite fertilizer, different particles produced are blended together with appropriate proportions. In this process in a large mixing drum particles are mixed as this drum rotates with some specific number of turns. When best mixing is done than on a conveyor belt the fertilizer is emptied, with the help of conveyer belt the fertilizers are transported to the bagging machine.

Bagging of fertilizers:

After the production of fertilizers, its bagging is done because fertilizers are to be supplied to farmers. For this the manufacturers have large hoppers where fertilizers are primary delivered and this hopper will release some fertilizers into bag with some fixed amount and to make the bag open for transfer for fertilizer a clamping device is used which will hold the bag to make it open, the surface on which the bag is kept is vibrating surface to ensure good packing, after filling of bag it is transported to another device that seals it and makes it close. When the bag full of fertilizer is sealed then it is conveyed to the palletizer so that at a time a large number of bags are made ready for shipment to the market and then to the farmers.

Waste products from fertilizer industries and their effects:

The nitrogen that is contained in fertilizers is applied in a small fraction to the soil which is actually taken by plants but the much larger portion is washed into the surrounding water bodies and a large portion is also filtered into the ground. As a result of which a significant quantity of nitrates is present in the water bodies which is used by the public. And with the intake of excessive nitrates the urinary and kidney system of the human body will not work properly. It is more harmful to small children and it is carcinogenic. It has been studied that there are some bacteria in the soil that can convert the nitrates into nitrite ions and when these nitrite ions are taken up into the body they can get into bloodstream and they get attached to hemoglobin which will not be able to restore oxygen and result in danger of life and various health problems.

Struvite:

There is a different type of scenarios for the production of struvite across the world and one of them is source separated. Source separation means separating the urine from human feces by the use of different technologies like ECOSAN because there are sufficient nutrients available in urine like N, P and K which can be used as a raw material for the production of struvite. Due to complex infrastructure needs like the construction of new pipe networks or integrating new facilities or modification of old facilities struvite precipitation from urine streams is not commonly practiced. For the full-scale adaptation of struvite precipitation, there are difficult challenges like to alter the existing wastewater infrastructure parts like toilets and pipes (EAWAG: Swiss Federal Institute of Aquatic Science and Technology, 2008)[26]. Struvite has octahedral structure and its SEM analysis is done by different researchers, it has a rod-like irregularly shaped crystals as shown in Figs. 2 and 3 respectively.

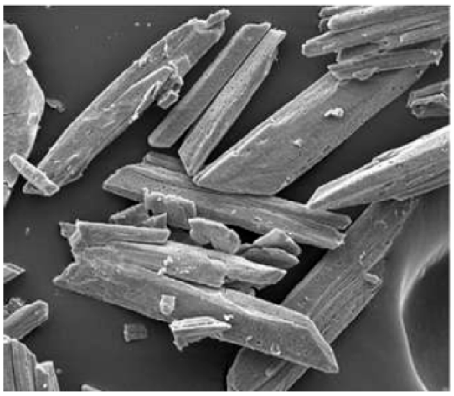

Fig. 2. Rod-like an irregular crystal of struvite[27].

Fig. 3. Irregular crystals of struvite[28].

There are large variations in different struvite precipitation scenarios as with the addition of phosphorus recovery there is also recovery and enhancement of nitrogen from the urine. Bisinella de Faria *et al*. (2015) studied and observe that the struvite precipitation with urine separated plants uses the activated sludge process and anaerobic digestion scheme of WWTP and also studied scenarios that have not used the digestion process and activated sludge process but uses the primary clarification for enhancement of recoveries of nutrients. There is nitrogen recovery from nitrogen-rich effluent in two of the scenarios and also the use of nitrification or deammonification of the source for removal of nitrogen from the effluent.

Raw materials for struvite production:

Any effluent from WWTP which have the desired nutrients like nitrogen or phosphorus can be used as a raw source for struvite precipitation. This paper used the source separated urine as a raw source for struvite production. Urine is rich in phosphorus and ammonia but it lacks the desired amount of magnesium that is required for precipitation (Pradhan *et al.*, 2009), therefore externally magnesium source can be added for the precipitation of struvite. When stored urine is used it is stored for about three months to increase the pH for struvite precipitation as for recovery by struvite required pH more than 9 because by storing pH increases and when struvite is produced with fresh urine sodium hydroxide can be used for increasing pH.

Manufacturing process of struvite:

There can be different approaches for the manufacturing of struvite, different researches have used different techniques for the production of struvite but in this review recovery of nutrients is done as shown in Fig. 1 and here are some steps involved in the production of struvite. Primary, the urine which is the raw source is characterized for the nutrient present in it as from this the dosage of magnesium can find out because struvite precipitation occurs when the ratio of components in urine such as magnesium, ammonium, and phosphorus are in an equimolar ratio.

The required amount of urine is collected in a flask and its pH is measured. In the urine magnesium dosage is given and pH is increased up to 9.5 by adding sodium hydroxide of 0.5 *N*, secondly, the beaker is made an airtight and it is rotated on a magnetic stirrer for mixing and then it is kept undisturbed for 24 h for the precipitation. Thirdly, the precipitate is filtered with the use of dried filter paper of known weight and it is kept for drying at room temperature for 24 h and then it is taken out of filter paper and weight to know the quantity of struvite produced.

Comparison of struvite properties with P fertilizers:

For farmers and to manufacturing industries MAP or struvite is a new fertilizer as compared to regular P fertilizer. The characterization of P fertilizers generally depends on the presence of phosphorus in it and some other nutrients that are present in the fertilizer. The composition of recovered nutrients in struvite may have variation when compared with pure struvite in terms of organic and dry matter plus the nutrient in it. Sander de varies *et al.*[29] studied and observe that the struvite produced from SWTP in apeldoom contains 1.8% of N, 25% of P and 15% of magnesium which suggest that its P and N content are lower when compared with pure struvite.

Kratz *et al.* (2010) studied that the struvite solubility in water is not good but its solubility is better in neutral ammonium citrates and acids in comparison with the regular fertilizers containing P which is based on ammonium phosphate and calcium phosphate. And as a result of this, it is suggested that the P availability from struvite for a short time is lower when compared with regular P fertilizer, therefore, struvite is sometimes is known as slow release fertilizer.

Degrye *et al.* (2016) studied the comparison of struvite with regular P fertilizers in terms of effectiveness to provide nutrients to the soil. The fertilizers are ground and mixed through the soil, the results show that soluble regular P fertilizer and struvite both were quite effective in providing P to the soil having the wheat plant but when fertilizer was applied as granules then it is much more effective than struvite.

Comparison of carbon footprint of struvite and fertilizers:

Sander de vries *et al.*[29] in his study while replacing the struvite produced from the Netherlands to Western Africa observe the GHG emission from struvite and that of fertilizer. Emission from mineral fertilizer production in Western Africa and when it is transported to two different places Lome and Dakar are calculated and results in 1.36 tonne of carbon dioxide per tonne of P_2O_5. But because of the transportation requirement to other two different places known as Togo and Abidjan the emission from production of mineral fertilizers are higher which is equal to 1.55 tonne of carbon dioxide per tonne of P_2O_5 while struvite, when produced in Netherland and transported to Western Africa, have emission around –0.82, –0.60, –0.54 tonne carbon dioxide per tonne of P_2O_5, which suggest that the removal of emission from using struvite in place of mineral fertilizer will result in an overall reduction of GHG gases and which will be equal to 2.18 in Dakar, 2.14 in Abidjan and 1.90 in Lome tonne of carbon dioxide per tonne of P_2O_5.

Practical application of struvite:

Struvite is as slow release fertilizer and is used on the ryegrass, and it is studied that from struvite the rate of P taken by plants is 100%[30]. On different crop plants, vegetables, flowers and in garden struvite has been used with success and the results of the plant growth show that struvite can be used as an alternative of fertilizer[31]. Ayla *et al.* (2013) studied the application of struvite on maize and tomato and found that when the different dosage of struvite was applied it significantly affects the fresh as well as dry weight and also affect the nutrient uptake by plants. Struvite when applied at higher dosages that is two times, three times and four times and compared it with the regular NPK it was found that N, Mg and P taken by plants were higher at these dosages of struvite. For proper growth and nutrients uptake of maize and tomato, it was found that 5.71 g of struvite per kilogram of soil is appropriate.

Struvite and DAP together applied to wheat crop the result shows of providing optimum early as well as late P uptake and shows an improved efficiency of overall P use (Peter *et al.*, 2015). When compared with calcium phosphates, struvite is more soluble than it at alkaline pH and therefore it can be used in calcareous soil as a potential P fertilizer[32].

Struvite when used in the agricultural sector in place of fertilizer than it would be profitable. For the agricultural practice of 2.6 hectars of land, production of 1 kg per day of struvite is enough and it can be applied at 40 kg per hectare per annum as phosphorus (EFMA 2000)[33]. 1 kg of struvite per day could be recovered from a 100-meter cube of wastewater and can be used for creating an eco-friendly environment as it reduces the need for using chemical fertilizer and ultimately which reduces the use of natural phosphate rock and minimizing its degradation.

The significance of struvite precipitation:

Urine has a high percentage of N, P, K presents in it and these are primary nutrients for crop growth (Esrey *et al.*, 2001). By struvite formation, these nutrients can be recovered which can be used as an alternative to fertilizers in a crop field. Along with N and K, P is the important nutrient for fertilizers. The demand of Phosphorus is increasing globally to manufacture fertilizers[3] and as a result there is depletion of natural phosphorus rocks, hence the major way to stop this depletion is to recover this nutrient from urine by forming struvite, which in turn will help in reducing the depletion of natural minerals.

With the increase in industrialization the climate changes occurs and there is imbalance in the environment, fertilizers industries also contribute to these climate changes by greenhouse gas emission as for production of fertilizers they required phosphate ores to get transported at sites, at the time of fertilizers production they emit carbon and when the product is ready it has to be transported to market, as a result of overall production and transportation they emit greenhouse gases. Struvite, when produced in a decentralized manner, will not only have decreased emissions but also have the cheap cost of it which attracts the customers. There are a lesser number of fertilizers manufacturing industries and the demand of producing more and more fertilizers have made the workload on these industries larger but by the recoveries of the nutrients like that of phosphorus and nitrogen, the load on these industries can be reduced. The chemical fertilizers industries have to export the fertilizers to distribute to longer distances because there is less number of industries due to which the pollution from transport vehicle is of greater extent and cost of these fertilizers are always high. By resource recovery as a small scale industry at different places will make this issue to be minimized as transportation of fertilizers to longer distances is eliminated.

Conclusion

Urine is rich in nutrients like nitrogen, phosphorus and potassium and for producing chemical fertilizers nitrogen, phosphorus and potassium as raw materials in different forms are used which is exploiting the natural resources hence by the recovery of nutrients the production of these chemical fertilizers can be minimized. Fertilizer industries required phosphate for producing fertilizers which are getting depleted by them so by the recovery of these nutrients in the form of struvite the natural minerals depletion can be minimized. It is also not easy to transport urine of large volume for its application in fields but solid or MAP form can be transported to large volumes which are cheap, also it is very cost effective to use the struvite. Fertilizers industries are also producing carbon foot print causing global climate change, use of struvite will help in reducing carbon foot print and controlling the climate changes. Struvite also has good efficiency in P uptake as compared to regular fertilizer hence it can be used as an alternative of fertilizer.

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